METHOD FOR SUPPLYING SLURRY TO POLISHING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to a method for supplying a slurry, particularly having an agglomerating property, and a slurry feeder suitable for use with a polishing apparatus for chemical mechanical polishing a polishing object.

The present invention also relates to a slurry feeder for feeding a slurry (polishing fluid) to a main body of a polishing apparatus for polishing a surface of a polishing object such as a semiconductor wafer and so on to an even surface and a mirror-finished surface, a polishing apparatus having a main body thereof and the slurry feeder, and a method for an operation of the slurry feeder.

Hitherto, the circuit wiring becomes finer and the distance between wires becomes narrower as the integration of semiconductor devices develops. In particular, in the case of photolithography having a line width of 5 micron or smaller, the allowable focal depth is so shallow that a high degree of evenness on the imaging plane of a stepper is required. Therefore, the surface of a semiconductor wafer has to be made even. One of the methods for flattening the surface of a semiconductor wafer involves polishing the surface of the wafer with a chemical mechanical polishing apparatus.

Fig. 8 illustrates an example of the essential portion of a chemical mechanical polishing apparatus. This apparatus has a turntable 142 with a polishing cloth (a

polishing tool) 140 attached on top thereof, a top ring 144 for rotatably pressing and holding a semiconductor wafer W as a polishing object, and a slurry feed nozzle 146 for feeding the polishing cloth 140 with slurry Q. The top ring 144 is connected to a top ring shaft 148 and held with an air cylinder, although not shown in the drawing, so as to be vertically movable. The top ring 144 has an elastic mat 150, e.g., a polyurethane mat, attached closely to the bottom surface thereof, to hold the semiconductor wafer W. The top ring 144 also has a cylinder-shaped guide ring 152 disposed at an outer edge portion thereof in order to prevent the top ring 144 from falling down from the bottom surface thereof during the polishing operations. The guide ring 152 is fixed to the top ring 144, and the bottom end surface of the guide ring 152 is protruding from the holding surface of the top ring 144 and provided with a depressed portion inside the bottom end thereof for holding the semiconductor wafer W.

With this arrangement of the chemical mechanical polishing apparatus, the semiconductor wafer W is held under the elastic mat 150 below the top ring 144. The semiconductor wafer W is pressed against the polishing cloth 140 on the turntable 142 with the top ring 144 and polished while rotating the turntable 142 and the top ring 144 and moving the semiconductor wafer W relatively to the polishing cloth 140. The slurry Q is supplied to the polishing cloth 140 from the slurry feed nozzle 146 during the polishing operations.

In order to allow a good polishing of the semiconductor wafer W with the chemical mechanical polishing apparatus, a slurry feeder is required which can stably feed the chemical mechanical polishing apparatus with the slurry (polishing or grinding fluid) at a constant concentration and a flow rate. The slurry feeder generally may include, for example, a stock solution tank for storing a stock solution of slurry, an preparation tank for adjusting the concentration of the slurry by diluting the slurry stock solution with a deionized water (pure water), a chemical liquid or the like to a given concentration, a slurry supply tank for temporarily storing the slurry adjusted in the preparation tank, and a slurry feed pipe for feeding the slurry from the slurry supply tank to the slurry feed nozzle 146 of the chemical mechanical polishing apparatus.

The conventional slurry feed pipe connecting the slurry supply tank to the chemical mechanical polishing apparatus adopts a so-called general circulation and supply system for discharging the slurry with roller pump from the circulating line to a table in the chemical mechanical polishing apparatus. This slurry feed pipe is provided with a circulating pipe for returning the slurry discharged from the slurry supply tank back to the slurry supply tank and a pipe branched from the circulating pipe for feeding the slurry to the chemical mechanical polishing apparatus. The slurry feed pipe is arranged so as to carry out the circulating operations for returning the slurry discharged

from the slurry supply tank with a circulating pump disposed in the circulating pipe to the slurry supply tank, even if the chemical mechanical polishing apparatus is operated for polishing or idling.

It is to be noted herein that slurry having an agglomerating property becomes more likely to agglomerate into particles having larger particle sizes, when the slurry is made in a fluid state. Therefore, if such slurry is used for this invention, it may present the problem that the agglomeration of the slurry may be accelerated when the slurry is stayed always in a fluid state by carrying out the circulating operations by means of the circulating pump in the manner as described above. In other words, the above feeding system cannot suspend the circulation operations of the circulating pump and the slurry has to be always circulated unless all the chemical mechanical polishing apparatuses are brought into an idling status. Otherwise, the agglomeration of the slurry would be accelerated.

Recent years, in the step of manufacturing semiconductor devices, there is the increasing demand that plural device layers are formed on a semiconductor wafer. In order to accurately form plural device layers, it is needed to make a surface of a layer covering each device layer flat and mirror-finished, and a polishing apparatus is used. The polishing apparatus includes a main body having turntables, each rotating at an independent number of rotations, and a top ring, and a slurry feeder. Between

the turntable and the top ring is disposed a polishing object such as a semiconductor wafer, and the surface of the polishing object is polished to an even and mirror-finished surface by rotating the turntable while feeding a slurry for use in polishing.

The slurry feeder is required to supply a slurry (polishing fluid) continually to the polishing apparatus. In order to prevent interruption of the supply of the slurry during the process of polishing, a buffer tank is disposed which contains a slurry of a capacity that can polish at least one sheet of a semiconductor wafer. The buffer tank is provided with a stirring device so as to stir the slurry well in order to prevent the slurry from being stayed in the buffer tank and polishing particles from settling to make the concentration of the slurry irregular. The stirring device can stir the slurry in the buffer tank to keep a uniform concentration of the slurry to be fed to the polishing apparatus and enable polishing the polishing object at a high accuracy.

SUMMARY OF THE INVENTION

The present invention has been made with the above situation taken into account and the object of the present invention is to provide a method for supply of slurry and a slurry feeder, which can feed a chemical mechanical polishing apparatus with slurry, including slurry with an agglomerating property, in an appropriate manner without causing the acceleration of agglomeration of the slurry.

As such a conventional slurry feeder has the buffer

tank with the stirring device, however, the apparatus is rendered complex in structure and the stirring causes raising the temperature of the slurry to render the cooling load of the slurry high.

The present invention has been made with the above disadvantages taken into account and it has the object to provide a slurry feeder having a simplified structure capable of feeding a slurry having a uniform concentration, a polishing apparatus installed with the slurry feeder, and a method for the operation of the slurry feeder.

In order to achieve the object as described above, the present invention provides a method for the supply of slurry from a slurry supply tank for storing slurry at a given concentration to a chemical mechanical polishing apparatus for polishing a polishing object, wherein the operations of a slurry feed pump are suspended during the period of time other than during the time of the operations of feeding the slurry to the chemical mechanical polishing apparatus.

The present invention also provides a method for feeding all the slurry discharged from the slurry supply tank by means of a slurry feed pump to the chemical mechanical polishing apparatus in process of operation.

The present invention is characterized in that the slurry feeder having the slurry supply tank for storing the slurry at a given concentration and a slurry feed pipe for feeding the slurry from the slurry supply tank to the chemical mechanical polishing apparatus with the slurry

feed pump is provided with a control system for suspending the operations of the slurry feed pump for feeding the slurry to the chemical mechanical polishing apparatus during the period of time other than during the time of feeding the slurry to the chemical mechanical polishing apparatus in process of polishing.

The present invention is further characterized in that a plurality of turntables for use with the chemical mechanical polishing apparatus is disposed and that the supply pump is disposed for each of the turntables.

Moreover, the present invention is characterized in that the slurry feeder is provided with an preparation tank for adjusting the stock solution of the slurry to a given concentration by mixing the stock solution thereof with a deionized water or a chemical liquid and for feeding the slurry of the given concentration to the slurry supply tank, and the control system is arranged so as to suspend the circulating operations for returning the slurry discharged from the preparation tank back to the preparation tank and the stirring operations for stirring the slurry in the preparation tank during the period of time other than during the time of adjusting the concentration of the slurry by diluting it in the preparation tank.

Additionally, the present invention is characterized in that a portion of the slurry supply tank connected to the slurry feed pipe is disposed so as to fail to discharge the slurry agglomerate settled to the bottom portion of the slurry supply tank into the slurry feed pipe by locating an

exit for discharging the slurry above the bottom of the slurry supply tank.

In order to achieve the objects, for example, as shown in Fig. 9, a slurry feeder according to the present invention, comprises a slurry feeder 252 for feeding a given slurry to a polishing apparatus 251 and a slurry supply tank 212 for storing the slurry to be fed to the polishing apparatus 251, wherein the slurry is fed at a flow rate Q from the slurry supply tank 212 to the polishing apparatus 251 and, when the polishing in the given slurry is allowed to settle at a sedimentation velocity V, the horizontally sectional area of the slurry supply tank 212 is set to become smaller than Q/V. The configuration of feeding the slurry at the flow rate Q can be achieved typically by locating a pump for feeding the slurry at the flow rate Q.

As the horizontally sectional area of the slurry supply tank is formed so as to become smaller than Q/V, the vertical flow velocity of the slurry in the slurry supply tank can be made faster than the sedimentation velocity of the polishing particles in the slurry and the slurry is allowed to be stirred well by flowing the slurry in the storage tank and to sustain the concentration of the slurry at a constant level. The slurry supply tank is configured such that, in usual cases, the slurry enters from the vertical top portion thereof and it is discharged from the vertical bottom portion thereof. The sedimentation velocity of the polishing particles in the slurry means a

velocity at which one polishing particle in the slurry settles in a solution (typically a deionized water) by means of gravity.

In order to achieve the object, the present invention provides a polishing apparatus, as shown in Fig. 9, which comprises a slurry feeder 252, a polishing table 242 to which to feed the slurry from the slurry feeder 252, and a slurry-returning line 308 through which the slurry fed from the slurry feeder 252 and not used for the polishing table 242 is returned to the slurry supply tank 212.

With the arrangement of the polishing apparatus in the manner as described above, the polishing can be effected by loading a polishing object on the polishing table and feeding the slurry at a constant concentration from the slurry feeder to the polishing apparatus, and the slurry not used for the polishing table is returned to the slurry supply tank for re-use by circulating the slurry. As the slurry in the slurry supply tank is not stirred with a stirring device, the cooling load of the slurry can be made small upon using the slurry by circulating. Further, the concentration of the slurry can be made constant for sure when the returning flow velocity of the slurry in the slurry-returning line is set to be within a given scope in which the concentration of the slurry is made constant.

In order to achieve the object, the present invention provides a method for the operation of the slurry feeder having a slurry supply tank for storing the given slurry to

be fed to the polishing apparatus, wherein a flow rate of the given slurry to be fed from the slurry supply tank to the polishing apparatus is set in such a manner that the flow velocity of the slurry in the slurry supply tank becomes faster than the sedimentation velocity of the polishing particles in the given slurry.

As the flow velocity of the slurry in the slurry supply tank is set to become faster than the sedimentation velocity of the polishing particles in the given slurry, the slurry can be fed to the polishing object at a constant concentration.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a system configuration diagram showing an example of a polishing apparatus according to the present invention.

Fig. 2 is an illustration of a state of a variation in particle sizes of the slurry having a highly agglomerating property upon carrying out the circulating operations for returning the slurry discharged from the slurry supply tank 30 back to the slurry supply tank 30 when the amounts of the slurry is set at 475 ml per minute.

Fig. 3 is an illustration of a state of a variation in particle sizes of the slurry having a highly agglomerating property upon carrying out the circulating operations for returning the slurry discharged from the slurry supply tank 30 back to the slurry supply tank 30.when the amounts of the slurry is set at 200 ml per minute.

Fig. 4 is an illustration of a state of a variation in particle sizes of the slurry having a highly agglomerating property upon carrying out the circulating operations for returning the slurry discharged from the preparation tank 20 back to the preparation tank 20 when the amount of the slurry discharged from the pump (the amount of the slurry to be circulated) is set at 5 liters per minutes.

Fig. 5 is an illustration of a state of a variation in particle sizes of the slurry having a highly agglomerating property upon carrying out the circulating operations for returning the slurry discharged from the preparation tank 20 back to the preparation tank 20 when the amount of the slurry discharged from the pump (the amount of the slurry to be circulated) is set at 2 liters per minute.

Fig. 6 is an illustration of a state of a variation in particle sizes of the slurry having a highly agglomerating property upon carrying out the circulating operations for returning the slurry discharged from the preparation tank 20 back to the preparation tank 20 when the amount of the slurry discharged from the pump (the amount of the slurry to be circulated) is set at 1 liter per minute.

Fig. 7 is a brief sectional view showing a portion in the vicinity of the bottom portion of the slurry supply tank 30 (and the preparation tank 20).

Fig. 8 is a view showing an essential portion of an

example of a chemical mechanical polishing apparatus.

Fig. 9 is a block diagram showing the configuration of the polishing apparatus according to an embodiment of the present invention.

Fig. 10 is a table showing the results of measurement for a variation of the concentrations of the slurry fed by changing the flow rate of the slurry circulating through the slurry feeder of the polishing apparatus of Fig. 9.

DESCRIPTION OF REFERENCE NUMERALS AND SYMBOL

1: slurry feeder

10: stock solution tank

20: preparation tank

30: slurry supply tank

40 (40-1, 2, 3, 4): chemical mechanical polishing apparatus

61: deionized water (or chemical solution) line

62: stock solution feed pipe

63: solution feed pipe

64: circulating pipe

67 (67-1, 2, 3, 4): slurry feed pipe

68 (68-1, 2, 3, 4): circulating pipes

71: stock solution feed pump

72: solution feed pump

73-1, 2, 3, 4: slurry feed pumps

81: opening-closing valve

82: opening-closing valve

83: opening-closing valve

84-1, 2, 3, 4: opening-closing valves

85-1, 2, 3, 4: opening-closing valves

87-1, 2, 3, 4: opening-closing valves

88: three-way switching valve

146: slurry feed nozzle

201, 202: stock solution tank

205: first pump

209: mixing tank

212: slurry supply tank

217: second pump

241: main body

251: polishing apparatus

252: slurry feeder

H: exhaust liquid

W: semiconductor wafer (a polishing object)

DETAILED DESCRIPTION OF THE INVENTION

The modes of practicing the present invention will be described in more detail with reference to the accompanying drawings. Fig. 1 is a system configuration diagram illustrating an example of a polishing apparatus according to the present invention. As shown in the drawing, the polishing apparatus includes a slurry feeder 1 having, for example, a stock solution tank 10 with a stock solution of slurry stored therein, an preparation tank 20 for adjusting the concentration of the stock solution of the slurry to a given concentration by diluting the stock solution thereof with a deionized water (or a chemical solution) and a slurry supply tank 30 for temporarily storing the slurry of the given concentration in the preparation tank 20, and a

plurality (four apparatuses in this embodiment) of chemical mechanical polishing apparatuses 40 (40-1 to 40-4, inclusive) to which the slurry is fed from the slurry supply tank 30 of the slurry feeder.

To the preparation tank 20 is connected a deionized water (or chemical solution) line 61 through an opening-closing valve 81, and the preparation tank 20 is in turn connected to the stock solution tank 10 with a stock solution feed pipe 62 having a stock solution feed pump 71 and an opening-closing valve 82. Further, the preparation tank 20 is connected to the slurry supply tank 30 with a solution feed pipe 63 installed with an opening-closing valve 83, a solution feed pump 72 and a three-way switching valve 88 that in turn is connected to a circulating pipe 64 communicating with the preparation tank 20.

To the slurry supply tank 30 is connected a slurry feed pipe 67 at the discharging side thereof. The slurry feed pipe 67 is branched into four branch slurry feed pipes 67-1, 67-2, 67-3 and 67-4 in a tree form. To the four branch slurry feed pipes 67-1, 67-2, 67-3 and 67-4 are connected opening-closing valves 84-1, 84-2, 84-3 and 84-4, slurry feed pumps 73-1, 73-2, 73-3 and 73-4, and opening-closing valves 85-1, 85-2, 85-3 and 85-4, respectively.

The top end of each of the branch slurry feed pipes 67-1, 67-2, 67-3 and 67-4 communicates with the slurry feed nozzle 146 (Fig. 8) of each of the chemical mechanical polishing apparatuses 40-1, 40-2, 40-3 and 40-3, respectively. On the other hand, circulating pipes 68-1,

68-2, 68-3 and 68-4 branched from the slurry feed pipes 67-1, 67-2, 67-3 and 67-4 are connected at the upstream side of opening-closing valves 85-1, 85-2, 85-3 and 85-4 of the slurry feed pipes 67-1, 67-2, 67-3 and 67-4, respectively. Each of the circulating pipes 68-1, 68-2, 68-3 and 68-4 is then united into a circulating pipe 68 that in turn is connected and returned to the slurry supply tank 30. Further, the circulating pipes 68-1, 68-2, 68-3 and 68-4 are installed with opening-closing valves 87-1, 87-2, 87-3 and 87-4, respectively.

The chemical mechanical polishing apparatuses 40-1, 40-2, 40-3 and 40-4 have each substantially the same configuration as that in the embodiment with reference to Fig. 8. Then, the operations of the polishing apparatus will be described in more detail. In the following description, the driving of each pump and valve may be controlled with a control unit (a control system) for electrically controlling the driving of the pumps and valves.

As the opening-closing valve 82 is opened and the stock solution feed pump 71 is driven, the slurry stock solution is fed from the stock solution tank 10 to the preparation tank 20. At the same time, the opening-closing valve 81 is opened to supply a deionized water (or a chemical solution) from a deionized water (or chemical solution) line 61 to the preparation tank 20 in which the slurry stock solution is diluted with a deionized water (or chemical solution) to a given concentration.

During the adjustment of the concentration of the slurry in the preparation tank 20 by diluting the slurry with the deionized water or chemical solution, the solution in the preparation tank 20 may be mixed by rotating the solution with a stirring impeller, although not shown, mounted in the preparation tank 20, or by circulating the slurry in the preparation tank 20 from the solution feed pipe 63 through the circulating pipe 64 by opening the opening-closing valve 83 to switch the three-way switching valve 88 to the side of the circulating pipe 64 and driving the solution feed pump 72. During the period of time other than during the time of the adjustment of the slurry by dilution, the circulating operations for circulating the slurry discharged from the preparation tank 20 back to the preparation tank 20 and the stirring operations for stirring the slurry with the stirring impeller in the preparation tank 20 are suspended.

The slurry to be used in this embodiment may be in an agglomerating nature in which polishing particles agglomerate into a larger mass when stress is imposed. More specifically, they may include SS-25 (product of Cabot), ILD 1300 (product of Rodel), and PLANERLITE 4213 (product of Fujimi).

The slurry adjusted to a given concentration in the preparation tank 20 is then transferred to the slurry supply tank 30 by switching the three-way switching valve 88 to the side of the solution feed pipe 63 and driving the solution feed pump 72.

For example, when the polishing operations are carried out by the chemical mechanical polishing apparatus 40-2, the opening-closing valves 84-2 and 85-2 are opened and the slurry feed pump 73-2 is driven to feed the slurry in the slurry supply tank 30 to the chemical mechanical polishing apparatus 40-2. More specifically, as shown in Fig. 8, the slurry is fed from the slurry feed nozzle 146 onto the polishing cloth 140 to polish the semiconductor wafer W. During the polishing operations, the opening-closing valve 87-2 is closed to feed all the slurry supplied by driving the slurry feed pump 73-2 to the chemical mechanical polishing apparatus 40-2 and to cause no slurry to circulate into the slurry supply tank 30.

Further, during the polishing operations with the chemical mechanical polishing apparatus 40-2, all the opening-closing valves 84-1, 84-3 and 84-4, 85-1, 85-3 and 85-4 as well as 87-1, 87-3 and 87-4 of the rest of the chemical mechanical polishing apparatuses, i.e., 40-1, 40-3 and 40-4, respectively, which is not subjected to the polishing operations, are closed and the slurry feed pumps 73-1, 73-3 and 73-4 are suspended to allow no slurry to be transferred into the pipe system.

In other words, in accordance with the present invention, the operations of the slurry feed pumps 73-1, 73-3 and 73-4 for the chemical mechanical polishing apparatuses 40-1, 40-3 and 40-4, respectively, are suspended during idling. At the same time, all the slurry discharged from the slurry supply tank 30 by the slurry

feed pump 73-2 is fed to the chemical mechanical polishing apparatus 40-2 in process of polishing.

Suspending the circulation of the slurry in the slurry supply tank 30 and feeding the slurry exclusively to the chemical mechanical polishing apparatus or/and apparatuses 40-1, 40-2, 40-3 or/and 40-4 in process of polishing are for the reasons as will be described hereinafter. Figs. 2 and 3 are graphs each illustrating a state in which particle sizes of the slurry are varied upon the circulating operations for circulating the slurry having a highly agglomerating property discharged from the slurry supply tank 30, which is used in the embodiment as described above, back to the slurry supply tank 30. Figs. 2 and 3 illustrate the state of a variation in the particle sizes of the slurry when the pump amounts of the slurry discharged from the pump (the amounts of the slurry being circulated) are set at 475 ml per minute and 200 ml per minute, respectively.

For each of the central graphs of Figs. 2 and 3, the axis of abscissas represents the circulating time (in hr) for circulating the slurry and the axis of ordinates represents the particle sizes (in micron) of the slurry corresponding to a 50% Q value of a cumulative distribution curve. In Figs. 2 and 3, the axis of abscissas for each of the left-hand and right-hand graphs represents the particle sizes (in micron) of the slurry while the axis of ordinates for the left-hand graph represents a rate of distribution with respect of each particle size and the axis of

ordinates for the right-hand graph represents a rate (in %) of a cumulative distribution curve from the smaller particle sizes to the larger particle sizes. Further, the graphs at the left-hand side illustrate the distribution of particle sizes of the slurry before testing and the graphs at the right-hand side illustrate the distribution of particle sizes of the slurry after testing (in a final measurement time).

As shown in Figs. 2 and 3, it is found that the particle sizes of the slurry become larger as the amount of the slurry discharged from the pump becomes larger, while the particle sizes of the slurry are little varied as the amount of the slurry discharged therefrom becomes smaller. Therefore, as in the present invention, when the amount of the slurry to be fed is controlled so as to become smaller, the particle sizes of the slurry to be fed to the chemical mechanical polishing apparatuses 40-1, 40-2, 40-3 and 40-4 can be sustained within an appropriate given scope of the slurry particle sizes, and the semiconductor wafer W can be subjected to polishing operations in an optimal way.

In particular, in this embodiment, one slurry feed pump is connected to each one of the chemical mechanical polishing apparatus. This configuration can readily control the supply of the slurry to the chemical mechanical polishing apparatus in process of polishing and the suspension (idling) of the polishing operations in the manner as described above. Further, this configuration allows a ready supply of all the slurry in a state in which

the slurry is not agglomerating (or little agglomerating), to the chemical mechanical polishing apparatus in process of polishing without circulating the slurry discharged from the slurry supply tank 30.

Then, Figs. 4 to 6 are graphs each illustrating a state of a variation in particle sizes of the slurry having a highly agglomerating property, as used in this embodiment, upon carrying out the circulating operations for circulating the slurry to return the slurry discharged from the preparation tank 20 back to the preparation tank 20. Figs. 4 to 6 illustrate the states of variations in the particle sizes of the slurry, when the amounts of the slurry discharged from the pump (the amounts of the slurry to be circulated) are set to 5 liters per minutes, 2 liters per minute, and 1 liter per minute, respectively. The axes of abscissas and ordinates of each graph are the same as in the case of Fig. 2 or Fig. 3.

As shown in Figs. 4 to 6, it is found that the particle sizes of the slurry become larger as the amount of the slurry discharged from the pump becomes larger, while the particle sizes of the slurry little vary as the amount of the slurry discharged from the pump become smaller. Therefore, as in the present invention, when the amount of the slurry to be fed is rendered smaller by controlling so as to suspend the circulating operations for returning the slurry discharged from the preparation tank 20 back to the preparation tank 20 and the stirring operations for stirring the slurry in the preparation tank 20 during the

period of time other than during the time of the adjustment for diluting the slurry, the particle sizes of the slurry to be fed to the slurry supply tank 30 can be sustained within a given appropriate scope of particle sizes. This permits optimal polishing operations for polishing the semiconductor wafer W.

Fig. 7 is a brief sectional view showing a portion in the vicinity of the bottom portion of the slurry supply tank 30 (and the preparation tank 20). As shown in Fig. 7, the portion of the slurry supply tank 30 (and the preparation tank 20) connected to the slurry feed pipe 67 (and the solution feed pipe 63) is configured such that the top end of the slurry feed pipe 67 (and the solution feed pipe 63) protrudes upwardly from the bottom portion of the slurry supply tank 30 (and the preparation tank 20). The bottom portion of the slurry supply tank 30 (and the preparation tank 20) with the slurry feed pipe 67 (and the solution feed pipe 63) protruding therefrom is provided with a trap section 35 in a depressed form.

This configuration can prevent the slurry agglomerate settled in the trap section from being discharged directly from the top end of the slurry feed pipe 67 (and the solution feed pipe 63), even if the slurry would be settled therein due to the suspension of the operations of the slurry supply tank 30 (and the preparation tank 20). This configuration can also assist in sustaining the particle sizes of the slurry to be fed at a given appropriate level and carrying out the optimal polishing operations for

polishing the semiconductor wafer W. In Fig. 7, a pipe 69 and an opening-closing valve 89 are disposed for discharging an exhaust liquid H, and these elements are omitted from Fig. 1.

In the above embodiment, circulating pipes 68, 68-1, 68-2, 68-3 and 68-4 are disposed to form a circulating pipe system in the slurry supply tank 30. It is to be noted herein, however, that this pipe system is not used in this embodiment because it is not needed to return the slurry to the slurry supply tank 30 by circulating the slurry. For this reason, it is not necessary to locate the pipe system in the present invention.

Although the present invention has been described by way of the embodiments as described above, it is to be understood that the present invention is not limited in any respect to the embodiments as described above and that it encompasses various variations within the scope and spirit claimed in the claims and described in the specification and drawings. It is also to be understood that any shape, configuration and material which are not referred to specifically in the claims and the description be encompassed within the scope and spirit of this invention as long as they can demonstrate the actions and effects sought to be achieved by the invention. It is needless to say that, for example, the chemical mechanical polishing apparatuses are not restricted to the one having the structure as shown in Fig. 8 and that it may have a variety of different structures.

The modes of practicing the present invention will be described with reference to the accompanying drawings. Fig. 9 is a block diagram showing the configuration of the polishing apparatus 251 for polishing a semiconductor wafer in accordance with an embodiment of the present invention. The polishing apparatus 251 may include a main body 241 of the polishing apparatus and a slurry feeder 252.

The main body 241 of the polishing apparatus may include a turntable 242, working as a polishing table for use with the present invention, and a top ring 243. The top ring 243 attaches and holds a semiconductor wafer W. The semiconductor wafer W is clamped between the turntable 242 and the top ring 243 and polished by rotating the turntable 242.

The slurry feeder 252 may include a stock solution tanks 201 and 202, each containing a stock solution of the slurry, a mixing tank 209 for mixing the stock solution of the slurry with a deionized water, a supply tank 212, working as a slurry supply tank for use with the present invention and feeding the slurry of a concentration in use to the main body 241 of the polishing apparatus, a first pump 205 for transferring the stock solution of the slurry to the mixing tank 209, and a second pump 217 for transferring the slurry to the main body 241 of the polishing apparatus.

A stock solution feed line 301 for feeding the stock solution of the slurry connects the stock solution tanks 201 and 202 and the mixing tank 209 and the first pump 205

is disposed in between. A stock solution detecting sensor 220 and a valve 203 are disposed in the stock solution feed line 301 in the vicinity of the stock solution tank 201, and a stock solution detecting sensor 221 and a valve 204 are disposed in the stock solution feed line 301 in the vicinity of the stock solution tank 202. A valve 206 is provided downstream of the first pump 205 of the stock solution feed line 301 in the vicinity of the mixing tank 209.

To the mixing tank 209 is connected a deionized water feed line 302 for feeding a deionized water from a plant line, although not shown in the drawing, and the deionized water feed line 302 is installed with valves 207 and 208. The valve 207 is located in the vicinity of the mixing tank 209.

Liquid level detecting sensors 222, 223 and 224 are mounted in the order of liquid level height on the mixing tank 209 in a generally cylindrical form, which is disposed in a vertical way. The liquid level detecting sensor 224 is disposed to detect the lowermost liquid level. Further, an overflow line 303 is disposed on the mixing tank at the level higher than the level detected by the liquid level detecting sensor 222 to allow an overflow of the mixed slurry.

A mixed slurry feed line 304 connects the mixing tank 209 to a slurry supply tank 212. The mixed slurry feed line 304 is in turn provided with a valve 211. The mixed slurry feed line 304 is branched at the location upstream

of the valve 211 into a discharging line 305 which in turn is provided with a valve 210. The mixed slurry feed line 304 is further connected to the uppermost portion of the slurry supply tank 212 or in the vicinity of the uppermost portion thereof. Therefore, the mixed slurry is allowed to flow vertically downward from the top of the slurry supply tank 212 toward the bottom thereof.

The slurry supply tank 212 is provided with liquid level detecting sensors 225, 226 and 227 in the order of liquid level height. The liquid level detecting sensor 227 is disposed to detect the lowermost liquid level. Further, an overflow line 306 is disposed at the level higher than the liquid level detected by the liquid level detecting sensor 225 to allow an overflow of the slurry fed. The overflow line 306 is provided with a filter 213 that can work as reducing an amount of air entering into the slurry supply tank 212 and preventing foreign matters from entering into the slurry supply tank 212.

A slurry feed line 307 is connecting the slurry supply tank 212 to the main body 241 of the polishing apparatus and is provided with a valve 215 in the vicinity of the slurry supply tank 212. A second pump 217 is mounted on the slurry feed line 307 at the location downstream of the valve 215 and a damper 218 for controlling the pulsation of a discharging pressure from the second pump 217 is in turn mounted thereon at the location downstream of the second pump 217. A valve 231 is further provided on the slurry feed line 307 at the location downstream of the

damper 218 and in the vicinity of the main body 241 of the polishing apparatus. As the closed valve 231 is opened, the slurry is fed to the turntable 242.

A line is provided with a valve 214, the line connecting the slurry feed line 307 upstream of the valve 215 to the discharging line 305. Another line is disposed connecting the slurry feed line 307 downstream of the valve 215 to the discharging line 305 and provided with a valve 216. The slurry feed line 307 is further connected to the vertical bottommost portion of the slurry supply tank 212, thereby allowing the slurry flown vertically downward in the slurry supply tank 212 to be fed from the slurry supply tank 212 to the slurry feed line 307.

The slurry not fed to the turntable 242 from the slurry supply tank 212 is returned to the slurry supply tank 212 through a circulating line 308 for use as a slurry-returning path in accordance with the present invention. On the other hand, the slurry fed to the turntable 242 from the slurry supply tank 212 is discharged after use for polishing as a waste fluid into a discharging line 309 having a valve 232. The circulating line 308 is disposed so as to allow the returned slurry to flow vertically downward into the slurry supply tank 212.

The slurry is fed from the slurry feed line 307 to the turntable 242 of the main body 241 of the polishing apparatus through the valve 231 and used for polishing the semiconductor wafer W. A bypass line 310 is disposed bypassing the main body 241 of the polishing apparatus from

the slurry feed line 307 and provided with a valve 233 and connects the upstream side of a three-way valve 219 to the downstream side of the damper 218. Another bypass line 311 is branched from the circulating line 308 at the three-way valve 219 and connected to the discharging line 305. The slurry flowing through the circulating line 308 is returned to the slurry supply tank 212 in usual cases, however, it can also be discharged into the discharging line 305 without being returned to the slurry supply tank 212 by switching the three-way valve 219.

Then, a description will be given regarding the actions of the polishing apparatus 251 according to an embodiment of the present invention.

(1) The stock solution of the slurry is sucked from either one of the stock solution tanks 201 and 202, where the stock solution of the slurry is stored, through the valve 203 and the valve 204, respectively, by means of the first pump 205 and then fed to the mixing tank 209. When the stock solution of the slurry is to be sucked from the stock solution tank 201, the valve 203 is opened and the valve 204 is closed. On the other hand, when the stock solution of the slurry is to be sucked from the stock solution tank 202, the valve 204 is opened and the valve 203 is closed. The management of the amount of the stock solution of the slurry to be fed to the mixing tank 209 may be conducted by suspending the operation of the first pump 205 and closing the valve 206 when the liquid surface level of the slurry in the mixing tank 209 is detected by the

liquid level detecting sensor 224 of the mixing tank 209.

(2) After the stock solution of the slurry has been fed to the mixing tank 209, the valves 207 and 208 are opened to feed a deionized water to the mixing tank 209 from the deionized water feed line 302. The amount of the deionized water to be fed to the mixing tank 209 can be managed by suspending a pump for feeding the deionized water, although not shown, or closing the valve 207 when the liquid surface level of the solution in the mixing tank 209 is detected by the liquid level detecting sensor 223 of the mixing tank 209. The liquid level detecting sensor 222 is a sensor for sensing an overflow of the fluid from the mixing tank 209 in case where the liquid level detecting sensors 223 and 224 do not work. As the liquid level of the stock solution of the slurry has been detected by the liquid level detecting sensor 222, the first pump 205 is suspended and the valves 206, 207 and 203 (or 204) are closed.

(3) After the deionized water has been fed to the mixing tank 209, the closed valve 211 is opened to allow the diluted slurry in the mixing tank 209 to drop into the slurry supply tank 212 by means of gravity and transfer all the diluted slurry to the slurry supply tank 212. It is to be noted herein that the mixing tank 209 is located at the level adequately higher than the slurry supply tank 212.

(4) The steps (1) to (3) above, inclusive, are repeated until the liquid surface level of the slurry in the slurry supply tank 212 arises and the liquid surface

level thereof is detected by the liquid level detecting sensor 226. After the liquid level of the slurry in the supply tank 212 has been detected by the liquid level detecting sensor 226 and all the slurry in the mixing tank 209 has been transferred to the supply tank, then the valve 211 is closed. The management of transferring all the slurry in the mixing tank 209 may be effected by a timer control.

More specifically, after the liquid level of the slurry has been detected by the liquid level detecting sensor 226, the opened valve 211 is controlled to be closed by a timer, although not shown, that is set to start operating the valve 211 after the elapse of the time when the slurry in the total amount of 3 liters drops by gravity from the mixing tank 209 to the slurry supply tank 212. It is to be noted herein, however, that the transfer of the slurry in the total amount of 3 liters from the mixing tank 209 to the slurry supply tank 212 is set herein to have all the slurry transferred.

After the slurry has been fed to the slurry supply tank 212, the second pump 217 starts feeding the slurry to the main body 241 of the polishing apparatus through the slurry feed line 307 by means of the valve 215. The amount of the slurry discharged by the second pump 217 may be the addition of the amount of the slurry fed to the main body 241 of the polishing apparatus to the amount (5 liters per minutes or more) of the slurry circulated and returned through the circulating line 308 to the slurry supply tank

212. If it would not be necessary to feed the slurry to the main body 241 of the polishing apparatus, all the slurry discharged by means of the second pump 217 is circulated from the slurry feed line 307 through the circulating line 308 and returned to the slurry supply tank 212. At this time, the valve 231 is closed.

When the slurry is continually fed to the main body 241 of the polishing apparatus and the liquid level of the slurry in the supply tank 212 is not detected any longer by the liquid level detecting sensor 226, then the steps (1) to (4) above, inclusive, are carried out. When the liquid level of the slurry in the supply tank 212 is not detected any longer by the liquid level detecting sensor 227, the operation of the second pump 217 is to be suspended, and the polishing apparatus is to be halted.

It is preferred that, when the liquid level of the slurry is not detected in the supply tank 212 any longer by the liquid level detecting sensor 227, then it is set to remain the slurry in the slurry supply tank 212 at the amount larger than the total amount corresponding to the amount necessary for circulating the slurry through the circulating line 308 by the second pump 217, in addition to the amount of the slurry required for polishing one sheet of the semiconductor wafer W.

More specifically, it is safe that the polishing operation is carried out by means of the timer control for a given period of time after the liquid level detecting sensor 226 has not detected the liquid level of the slurry

in the supply tank 212 any longer and that the operation of the second pump 217 is suspended in order to prevent the idling of the second pump 217 after the liquid level detecting sensor 227 has not detected the liquid level of the slurry any longer.

Whether the stock solution of the slurry becomes empty in the stock solution tank 201 or the stock solution tank 202 is determined by the fact that the stock solution of the slurry is not detected any longer by a stock solution detecting sensor 220 or a stock solution detecting sensor 221, respectively, when the stock solution of the slurry is being sucked by the first pump 205. The reason for locating two of the stock solution tanks 201 and 202 is because the stock solution of the slurry can be fed continuously to the main body 241 of the polishing apparatus even if one of the stock solution tanks would become empty.

In other words, the arrangement of two of the stock solution tanks allows the stock solution to be sucked from either one of them by means of the first pump 205 even if the other tank would become empty. If one of the stock solution tanks would become empty, the operator can exchange the empty tank before the other tank become empty (for example, immediately after the one tank became empty).

When the liquid level detecting sensor 223 or 224 of the mixing tank 209 would not work, or when the slurry is kept feeding to the mixing tank 209 even if the sensor works, the upper limit of the fluid level of the mixed

slurry in the mixing tank 209 may be controlled by the liquid level detecting sensor 222. In other words, in the case where the liquid level of the mixed slurry is detected by the liquid level detecting sensor 222, the operation of the first pump 205 and a pump for feeding a deionized water, although not shown, are suspended. If the liquid level detecting sensor 222 would not also work or the first pump 205 or the pump for feeding the deionized water, not shown, would not be suspended even if the liquid level detecting sensor 222 would work, then the fluid is discharged from the overflow line 303 disposed at the upper side wall portion of the mixing tank 209.

If the liquid level detecting sensor 225 or 226 of the slurry supply tank 212 would not work or the fluid would be kept feeding in the slurry supply tank 212 even if the liquid level detecting sensor 225 or 226 would work, the valve 211 is closed which is controlled by the timer in the manner as described above. Therefore, no slurry is fed to the slurry supply tank 212. If the valve 211 would not be closed by the timer control and the liquid level of the slurry in the slurry supply tank 212 would further rise, then the fluid is discharged from the overflow line 306 disposed at the upper side wall portion of the slurry supply tank 212.

During the transferring step of the stock solution of the slurry from the stock solution tanks 201 or 202 to the mixing tank 209 by means of the first pump 205, the timer control is being carried out by means of a timer, although

not shown, so as to fail to interfere with the operation of other instrument for a certain period of time even if the stock solution detecting sensors 220 or 221 would not detect the stock solution of the slurry. If the stock solution of the slurry would not be detected by the stock solution detecting sensor 220 or 221 over the predetermined certain period of time, then the operation of the first pump 205 is suspended.

When the fluid in the mixing tank 209 is to be discharged, the closed valve 210 is opened. On the other hand, when the fluid in the slurry supply tank 212 is to be discharged, the closed valve 214 is opened. When the fluid is discharged from the slurry feed line 307 in order to subject the second pump 217 to maintenance, the opened valve 215 is closed and the closed valve 216 is opened.

Then, a description will be given regarding the shape, etc. of the slurry supply tank 212 (buffer tank) in this embodiment of the present invention. The slurry supply tank 212 is in a generally cylindrical shape and is disposed in a vertical way. The slurry supply tank 212 may have a tank diameter of 200 mm, a sectional tank area of 31,400 mm2, and a tank height of approximately 800 mm. The pipe size of each of the slurry feed line 307 and the circulating line 308 is 3/4 inch (the pipe inner diameter of 15.88 mm).

The circulating fluid amount (the amount of the fluid circulating through the circulating line 308) is 5 liters per minute or more. At this time, the vertical flow

velocity of the slurry in the slurry supply tank 212 is set to be 0.00264 m/s or higher and the flow velocity of the fluid in the circulating line is set to be 0.42 m/s or higher. Under those conditions, it is confirmed that this setting can avoid the sedimentation of the polishing particles in the slurry supply tank 212 and make the concentration of the slurry uniform. The generally cylindrical shape of the slurry supply tank 212 can serve in flowing the slurry in a smooth way.

Then, a description will be given with reference to the table of Fig. 10 and optionally to Fig. 9, regarding the results of measurement by means of the slurry feeder 252 in this embodiment for a variation in uniformity of the concentration of the slurry when the amounts of the slurry flowing in the slurry supply tank 212 and through the slurry feed line 307 and circulating through the circulating line 308 are changed. During this measurement, the valve 231 is closed. The pipe sizes of the slurry feed line 307 and the circulating line 308, and the tank size and the sectional tank size of the slurry supply tank 212 are set in the manner as described above.

The circulating amount of the slurry was divided into three cases, that is, 10 liters per minute for the case 1, 5 liters per minute for the case 2, and 1.4 liter per minute for the case 3. And a deviation of the concentration of the feeding slurry from the initial concentration thereof is measured for each case. At this time, the flow velocity through the pipe for each case is set: 0.842 m/s

for the case 1, 0.421 m/s for the case 2, and 0.118 m/s for the case 3; and the flow velocity in the slurry supply tank 212 is set: 0.00531 m/s for the case 1, 0.00265 m/s for the case 2, and 0.00074 m/s for the case 3. As the slurry (slurry), there is used a settling slurry of a ceria or alumina type and the initial concentration of the slurry is set to be 4.7% by weight for each of the case 1 and the case 2, and 4.5% by weight for the case 3.

The variation of the concentration of the slurry in the slurry supply tank 212 from the initial concentration thereof was found to be less than +/-4% for the case 1, less than +/-4% for the case 2, and less than +/-32% for the case 3. From these results, it was found that the cases 1 and 2 can satisfy the determination standard of less than +/-10%. Further, it is found from the above results that for the slurry feeder in this embodiment of the present invention, the slurry can be fed at a uniform concentration when the circulating flow rate is set to be 5 liters per minutes or greater.

It is preferred that the circulating flow rate of the slurry is set to be in the range of 5 to 22 liters per minute because a too fast circulating flow velocity of the slurry may adversely affect the polishing performance due to agglomeration of the polishing particles. It is to be noted herein that the slurry feeder 252 in this embodiment of the present invention does not require any type of a stirring device in order to stir the slurry in the slurry supply tank 212 so that there is no risk of raising the

temperature of the slurry arising otherwise by stirring the slurry with the stirring device. It is further preferred that the determination standard for the variation of the concentration of the slurry in the slurry supply tank 212 from the initial concentration thereof is set to be less than +/-5%.

Then, the mixing/diluting of the stock solution of the slurry with a deionized water in the mixing tank 209 may be carried out by utilizing the flow velocity at which the deionized water is fed to the mixing tank 209. It is preferred that the feeding flow velocity is set to be 0.332 m/s or higher and that a half (1.5 liter) or more of the amount of adjustment at the time of mixing/diluting at this flow velocity is set to have a feeding flow rate of 4 liters per minutes or higher. In this embodiment of the present invention, the outer diameter and the inner diameter of the pipe for the deionized water feed line 302 are set to be 12.7 mm and 9.5 mm, respectively.

(Effects of the Invention)

As described above, the present invention can demonstrate the remarkable effects that, even if the slurry for use with the chemical mechanical polishing apparatus is in an agglomerating nature, the slurry can be supplied to the chemical mechanical polishing apparatus in an appropriate state without accelerating the agglomeration of the slurry.

As described above, the present invention presents the advantages that the vertical flow velocity of the

slurry in the slurry supply tank can be made faster than the sedimentation of the polishing particles in the slurry because the horizontal sectional area of the slurry supply tank is set to be smaller than Q/V, that the concentration of the slurry in the slurry supply tank can be sustained at a constant level because the slurry is stirred due to the flow of the slurry through the storage tank, and that the concentration of the slurry to be fed to the polishing apparatus can be made constant.